

# Weight Management Using Lifestyle Modification in the Prevention and Management of Type 2 Diabetes: Rationale and Strategies

A statement of the American Diabetes Association, the North American Association for the Study of Obesity, and the American Society for Clinical Nutrition

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The prevalence of diabetes in the U.S. continues to rise by epidemic proportions. This increase parallels the rising rates of obesity and overweight observed over the past decade.<sup>1,2</sup> Indeed, as BMI increases, the risk of developing type 2 diabetes increases in a “dose-dependent” manner.<sup>3,4</sup> The prevalence of type 2 diabetes is 3–7 times higher in obese than in normal-weight adults, and those with a BMI > 35 kg/m<sup>2</sup> are 20 times more likely to develop diabetes than those with a BMI between 18.5 and 24.9 kg/m<sup>2</sup>.<sup>5,6</sup> In addition, weight gain during adulthood is also directly correlated with an increased risk of type 2 diabetes.<sup>3,7–9</sup>

Obesity also complicates the management of type 2 diabetes by increasing insulin resistance and blood glucose concentrations.<sup>10</sup> It is an independent risk factor for dyslipidemia, hypertension, and cardiovascular disease<sup>6,11–14</sup> and, thus, increases the risk of cardiovascular complications and cardiovascular mortality in patients with type 2 diabetes.<sup>15</sup>

The purpose of this statement is to review the important role of weight management in the prevention and management of type 2 diabetes and to describe strategies for achieving and maintaining a healthy body weight through lifestyle modification. The use of weight loss medications and bariatric surgery in the management of obesity will not be discussed in this document. Pharmacotherapy can be a useful adjunct to lifestyle modification in the long-term management of obesity in selected patients.<sup>16</sup> Weight loss medications may be considered for those with a BMI ≥ 30 or those with a BMI ≥ 27

plus obesity-related comorbid conditions. Weight loss surgery may be a therapeutic alternative for patients with a BMI ≥ 40 or a BMI ≥ 35 plus comorbid conditions.<sup>16</sup> Comprehensive review articles that discuss the use of weight loss medications and surgery in the management of obesity have recently been published.<sup>17–20</sup>

## Benefits of weight loss

Weight loss is an important goal for overweight or obese persons, particularly those with type 2 diabetes, because it improves glycemic control.<sup>21</sup> Moderate weight loss (5% of body weight) can improve insulin action, decrease fasting blood glucose concentrations, and reduce the need for diabetes medications.<sup>22–28</sup> Moreover, improvement in fasting blood glucose is directly related to the relative amount of weight lost.<sup>28</sup> Moderate weight loss may not improve glycemic control in all obese patients who have diabetes,<sup>29</sup> however, and it is possible that patients with longstanding disease or severe pancreatic  $\beta$ -cell dysfunction are not as responsive to weight loss as those with less extensive disease. Marked weight loss (30% of body weight) following gastric bypass surgery can normalize glycemic control in more than two-thirds of extremely obese patients with type 2 diabetes.<sup>30–33</sup>

Weight loss has important additional health benefits in patients with diabetes because it improves other risk factors for cardiovascular disease<sup>22–27</sup> by decreasing blood pressure,<sup>34–38</sup> improving serum lipid concentrations (decrease in serum triglycerides, total cholesterol,

and LDL cholesterol and increase in serum HDL cholesterol concentrations),<sup>39–42</sup> and reducing serum markers of inflammation.<sup>43,44</sup>

Moderate weight loss and increased physical activity can prevent or delay the development of type 2 diabetes in high-risk groups, such as those with impaired glucose tolerance.<sup>45–47</sup> For example, data from the Diabetes Prevention Program (DPP) demonstrated that weight loss (7% of weight loss in the first year) and increased physical activity (150 min of brisk walking per week) reduced the 4-year incidence of type 2 diabetes by 58% in men and women with impaired glucose tolerance.<sup>45</sup> Lifestyle changes were nearly twice as effective as metformin therapy (31% reduction in incidence of diabetes) in preventing type 2 diabetes.<sup>45</sup>

## Indications and goals for weight loss therapy

Weight loss is recommended for all overweight (BMI 25.0–29.9 kg/m<sup>2</sup>) or obese (BMI ≥ 30.0 kg/m<sup>2</sup>) adults who have type 2 diabetes or who are at risk for this disease (Table 1). It is important to set a weight loss goal that is both *achievable and maintainable*. Even moderate weight loss of 5% of body weight can produce significant health benefits<sup>16,24,48–50</sup> and may be a reasonable initial goal for most patients. Better outcomes for long-term weight reduction occur when a reduced calorie diet is combined with increased physical activity and behavior therapy that is aimed at developing skills required to successfully change problematic eating and activity patterns.<sup>16,51</sup>

**Table 1. Risk Factors for Type 2 Diabetes**

- Age ≥ 45 years
- Overweight (BMI > 25 kg/m<sup>2</sup>\*)
- Family history of diabetes (i.e., parents or siblings with diabetes)
- Habitual physical inactivity
- Race/ethnicity (e.g., African Americans, Hispanic Americans, Native Americans, Asian Americans, and Pacific Islanders)
- Previously identified as pre-diabetes: impaired fasting glucose (IFG) or impaired glucose tolerance (IGT)
- History of gestational diabetes or delivery of a baby weighing > 9 lb
- Hypertension (≥ 140/90 mmHg in adults)
- HDL cholesterol ≤ 35 mg/dl and/or a triglyceride level ≥ 250 mg/dl
- Polycystic ovary syndrome
- History of vascular disease

\*May not be correct for all ethnic groups. Adapted from Ref. 105.

**Diet**

Weight loss occurs when energy expenditure exceeds energy intake. An energy deficit of 500-1,000 kcal/day will result in a loss of ~ 1-2 pounds/week and an average total weight loss of about 8% after 6 months.<sup>16</sup> Although weight regain is common, approximately two-thirds of weight that is lost by dieting is maintained at 1 year.<sup>52</sup> Severe calorie restriction that involves the use of a very-low-calorie diet (< 800 kcal/day) causes rapid weight loss of about 15-20% within 4 months. However, very-low-calorie diets are not recommended for most patients, because they do not result in greater long-term weight loss and have a higher risk of developing medical complications, such as gallstones, than low-calorie diets.<sup>53-55</sup> The National Heart, Lung, and Blood Institute (NHLBI) Obesity Education Initiative (OEI) Expert Panel recommends the use of a low-calorie diet that generates an initial deficit of 500-1,000 kcal/day and supplies at least 1,000-1,200 kcal/day for women and 1,200-1,600 kcal/day for men to treat obesity.<sup>51</sup> An alternative approach for

determining suggested energy intake goals for weight loss based on current body weight is shown in Table 2.<sup>17</sup>

A variety of diets have been proposed to treat obesity. Although many different dietary approaches may result in short-term weight loss, the limitation of most diets is poor long-term compliance and weight regain. The optimal dietary macronutrient composition that facilitates lasting and safe weight loss is not known.<sup>16</sup>

A low-fat (e.g., 25-30% of calories from fat) diet is considered the conventional therapy for treating obesity. Data obtained from obese persons who were successful at maintaining long-term weight loss,<sup>56</sup> diet intervention trials designed to decrease the risk of cardiovascular disease,<sup>57</sup> and randomized controlled trials that evaluated diet therapy for obesity<sup>58</sup> indicate that decreasing dietary fat intake (to 25-30% of total calories) results in decreased total energy intake and weight loss. Data regarding the long-term effect of a very-low-fat diet (≤ 15% of total calories from fat) on weight loss are limited because few studies have successfully achieved this level of intake.<sup>59</sup> Additionally, in some diabetic patients, the concomitant increase in carbohydrate intake can exacerbate the dyslipidemia (elevated

triglyceride, low HDL cholesterol levels) frequently associated with insulin resistance/type 2 diabetes.<sup>60-63</sup>

Recently, there has been increased interest in the use of low-carbohydrate diets as potential therapy for obesity. The results of five randomized controlled trials in adults<sup>64-68</sup> found that subjects randomized to a low-carbohydrate, high-protein/high-fat diet (~ 25-40% carbohydrate) achieved greater short-term (6 months),<sup>64-66</sup> but not long-term (12 months),<sup>64,67</sup> weight loss than those randomized to a low-fat diet (~ 25-30% fat, 55-60% carbohydrate). The data from these studies also found greater improvements in serum triglyceride and HDL cholesterol concentrations, but not in serum LDL-cholesterol concentration, in the low-carbohydrate than the low-fat group. In addition, glycemic control was better with low-carbohydrate than low-fat diet therapy in subjects who had type 2 diabetes.<sup>65,67</sup> Data from a study conducted in overweight adolescents found that altering dietary glycemic load by reducing both total carbohydrate content (45-50% of energy intake) and consuming low-glycemic index foods resulted in more weight loss when compared with a conventional low-fat (25-30%) diet.<sup>69</sup> Additional research is needed to clarify the long-term efficacy and safety of low-carbohydrate diets, particularly in patients with diabetes.

It is unlikely that one diet is optimal for all overweight/obese persons. Dietary guidance should be individualized to allow for specific food preferences and individual approaches to reducing energy intake.<sup>21,51</sup> A variety of strategies are available for decreasing energy intake. For example, lowering dietary energy density (e.g., by increasing fruit and vegetable intake and limiting foods that are high in fat) can reduce energy intake while maintaining a volume of food that might help control hunger.<sup>70</sup> Increasing portion control by reducing portion sizes,<sup>70</sup> using meal replacement products,<sup>41,71,72</sup> and following structured meal plans<sup>73,74</sup> can also enhance compliance with energy-deficit diets.

**Table 2. Alternative Approach for Estimating Energy Intake Goal of Initial Weight Loss Diet**

Body weight (lb)	Suggested goals for energy intake (kcal/day)*
150-199	1,000-1,200
200-249	1,200-1,500
250-299	1,500-1,800
300-349	1,800-2,000
> 350	2,000

\*The energy intake goals in this table would achieve an energy deficit that is slightly greater than the 500- to 1,000-kcal deficit recommended for moderate weight loss, allowing for potential errors in estimating the caloric value of foods consumed. Adapted from Ref. 17.

The American Diabetes Association, the North American Association for the Study of Obesity, and the American Society for Clinical Nutrition recommend setting an energy intake goal to achieve a 500–1,000 kcal/day energy deficit with a food intake pattern consistent with current recommendations for reducing the risk of comorbidities associated with obesity. Therefore, we recommend that the macronutrient content of the diet be based upon current dietary guidelines from the American Diabetes Association,<sup>21</sup> the American Heart Association,<sup>75</sup> and the National Cholesterol Education Program (NCEP)-Adult Treatment Panel (ATP III)<sup>76</sup> (Tables 3 and 4). These recommendations are based on current evidence regarding the effects of dietary intervention to reduce several coronary heart disease risk factors, including hypertension and elevated LDL cholesterol concentration,<sup>75,76</sup> which is an important consideration in patients with type 2 diabetes because of their increased risk of cardiovascular disease.<sup>76</sup> These recommendations may require modification, however, as new information is generated from additional diet intervention studies.

**Physical activity**

Physical activity is an important component of any weight management program. Although energy restriction by dieting is largely responsible for initial weight loss,<sup>16,77,78</sup> regular physical activity helps to maintain weight loss and prevent weight regain.<sup>51,79</sup> Regular exercise and aerobic fitness also improve insulin sensitivity and glycemic control,<sup>16,80,81</sup> may decrease the risk of developing diabetes,<sup>82</sup> and may reduce overall mortality in patients who have type 2 diabetes.<sup>83</sup>

The NHLBI OEI Expert Panel recommends that individuals engage in 30–45 min of moderate-intensity aerobic physical activity (40–60% of maximal oxygen uptake or 50–70% of maximum heart rate), 3–5 days per week initially, gradually increasing the duration and frequency.<sup>16</sup> This recommendation is in

**Table 3. Dietary Recommendations From the NCEP Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults**

Nutrient	Recommended Intake
Saturated fat*†	< 7% of total calories
Monounsaturated fat	Up to 20% of total calories
Polyunsaturated fat	Up to 10% of total calories
Total fat	25–35% or less of total calories
Carbohydrate‡	50–60% or more of total calories
Fiber	20–30 g/day
Protein	Approximately 15% of total calories
Cholesterol†	< 200 mg/day

\*The combination of *trans* fatty acids and saturated fat < 7%.  
 †If LDL cholesterol is not elevated and there is no preexisting cardiovascular disease, saturated fat and *trans* fat intake of < 10% of total calories; cholesterol < 300 mg/day.  
 ‡Complex carbohydrates from a variety of vegetables, fruits, and whole grains.  
 Adapted from Ref. 76.

agreement with that of several other health organizations, including the Surgeon General’s office, the American College of Sports Medicine, the American Diabetes Association, the American Heart Association, and the National Institutes of Health (NIH) Consensus Development Panel on Physical Activity and Cardiovascular Health.<sup>80,84–87</sup> A greater reduction in cardiovascular disease risk would be anticipated by increasing either the duration or intensity of physical activity.<sup>88</sup> Data from most weight loss studies suggest that 60–75 min of moderate intensity activity (e.g., walking) or 35 min of vigorous activity (e.g., jogging) daily is needed to maintain long-term weight loss.<sup>56,79,89</sup>

In previously inactive patients, an initial exercise program should be of a short duration (i.e., 10 min/day) of activity daily and gradually increase to 30 min/day of low-intensity activity.<sup>16,84</sup> Intensity can be increased as the patient’s strength and fitness improves.<sup>16,90</sup> In developing an activity program, the clinician should devise a plan that can be maintained without injury based on the patient’s current level of activity and readiness to increase activity. All individuals should be assessed regarding the need to undergo exercise stress testing before initiation of a moderate-intensity exercise program.<sup>86,91–93</sup> Exercise testing

should be performed at the discretion of the primary care physician before *vigorous* exercise, particularly in patients with diabetes.<sup>86,93,94</sup>

Achieving adherence to a physical activity program is challenging. A structured exercise program that involves planned, repetitive exercise is not required for maintaining weight loss; increasing daily physical activity, such as

**Table 4. Dietary Guidelines From the American Diabetes Association and the American Heart Association**

- Consume a variety of fruits, vegetables, grains, low-fat or nonfat dairy products, fish, legumes, poultry, and lean meats.
- Limit foods high in saturated fat, trans fatty acids, and cholesterol; substitute unsaturated fat from vegetables, fish, legumes, and nuts.
- Emphasize a diet rich in fruits, vegetables, and low-fat dairy products.
- Limit salt to 6 g/day (2,400 mg sodium) by choosing foods low in salt and limiting the amount of salt added to food.
- Limit alcohol intake to no more than 2 drinks per day (men) and 1 drink per day (women) in those who choose to drink alcohol.

Adapted from Refs. 21 and 75.

walking and using stairs, is also effective.<sup>95-97</sup> Exercise performed at home, rather than at a health club, reduces barriers of cost and travel time.<sup>98</sup> Also, exercise does not need to occur in a single session to be beneficial, and dividing activity into multiple, short bouts produces similar benefits and can enhance compliance.<sup>99,100</sup>

### Facilitating lifestyle change in an office practice

Making long-term changes to eating and activity behaviors is extremely difficult for most patients.<sup>16</sup> The role of the clinician is to encourage, monitor, and support the patient during this process. The office environment should be sensitive to the needs of obese persons. Appropriate chairs, examination tables, and restrooms and specialized equipment, such as large blood pressure cuffs, extra-large gowns, and scales that measure weight greater than 300 lb should be available. The physician and office staff should always be sensitive and encouraging, even when patients have been unable to lose weight. It is important that patients feel understood and supported, not guilty or embarrassed, at office visits.<sup>101</sup>

Several techniques can be used in the office setting to promote behavior change.<sup>51,102-104</sup> Initially, problem behavior(s) are identified, and specific, realistic goals are agreed upon. Setting small and achievable goals allows patients to experience success, which can be used as a foundation for additional lifestyle alterations. Strategies such as self-monitoring (daily records of food intake and physical activity), stimulus control (avoiding triggers that prompt eating), and problem solving (identifying barriers and ways to overcome them) can support the change process during follow-up visits. Frequent patient-provider contact (e.g., weekly or biweekly) is associated with better long-term weight loss maintenance.<sup>101</sup>

Within a clinical practice, providing appropriate behavior modification treatment can be difficult due to limited time and expertise on the part of physicians. Utilizing the support of a health care

professional (e.g., nurse, medical assistant, or dietitian) who could weigh patients, briefly review records, and praise their efforts may be beneficial. Additionally, physicians may choose to refer patients to a registered dietitian who has weight management experience or a legitimate commercial or self-help program available in the local community. At the present time, third-party reimbursement is available for medical nutrition therapy for diabetes but does not usually cover weight loss therapy.

### Maintaining weight loss

Long-term maintenance of weight loss is more challenging than initial weight reduction.<sup>101</sup> Some strategies that are associated with successful long-term weight loss include eating a diet low in calories (~ 1,400 kcal/day) and fat (24% of total energy intake), frequently monitoring body weight, and participating in regular physical activity (equivalent to 2,800 kcal/week or ~ 60 min of moderate activity/day).<sup>56,79</sup> Successful weight loss maintainers also reduced portion sizes and snacking, ate breakfast daily, ate meals away from home  $\leq 3$  times/week, and watched television less than 3 h per week on average.<sup>52,79</sup>

### Summary

In summary, overweight and obesity are strongly linked to the development of type 2 diabetes and can complicate its management. Obesity is also an independent risk factor for hypertension and dyslipidemia as well as cardiovascular disease, which is the major cause of death in those with diabetes. Moderate weight loss improves glycemic control, reduces cardiovascular disease risk, and can prevent the development of type 2 diabetes in those with pre-diabetes. Therefore, weight loss is an important therapeutic strategy in all overweight or obese persons who have type 2 diabetes or are at risk for developing diabetes.

### Specific recommendations

- Weight loss is recommended for all overweight (BMI 25.0–29.9 kg/m<sup>2</sup>) or

obese (BMI  $\geq 30.0$  kg/m<sup>2</sup>) adults who have, or who are at risk for developing, type 2 diabetes.

- The primary approach for achieving weight loss is therapeutic lifestyle change, which includes a reduction in energy intake and an increase in physical activity.
- A moderate decrease in caloric intake (500–1,000 kcal/day) will result in a slow but progressive weight loss (1–2 lb per week). For most patients, weight loss diets should supply at least 1,000–1,200 kcal/day for women and 1,200–1,600 kcal/day for men.
- Overweight or obese patients with diabetes are encouraged to adopt the dietary recommendations known to reduce the risk of coronary heart disease (outlined in Tables 3 and 4). In conjunction with a moderate reduction in caloric intake (500–1,000 kcal/day), this diet is likely to result in moderate weight loss as well as improvement in cardiovascular risk factors. Dietary guidance should be tailored to each person, allowing for individual food preferences and approaches to reducing caloric intake.
- Physical activity is an important component of a comprehensive weight management program. Regular, moderate intensity physical activity enhances long-term weight maintenance. Regular activity also improves insulin sensitivity, glycemic control, and selected risk factors for cardiovascular disease (i.e., hypertension and dyslipidemia), and increased aerobic fitness decreases the risk of coronary heart disease.
- Initial physical activity recommendations should be modest, based on the patient's willingness and ability, gradually increasing the duration and frequency to 30–45 min of moderate aerobic activity, 3–5 days per week, when possible. Greater activity levels of at least 1 h per day of moderate (walking) or 30 min per day of vigorous (jogging) activity may be needed to achieve successful long-term weight loss.



## REFERENCES

- <sup>1</sup>Harris MI, Flegal KM, Cowie CC, Eberhardt MS, Goldstein DE, Little RR, Wiedmeyer HM, Byrd-Holt DD: Prevalence of diabetes, impaired fasting glucose, and impaired glucose tolerance in U.S. adults: the Third National Health and Nutrition Examination Survey, 1988–1994. *Diabetes Care* 21:518–524, 1998
- <sup>2</sup>Mokdad AH, Ford ES, Bowman BA, Nelson DE, Engelgau MM, Vinicor F, Marks JS: The continuing increase of diabetes in the U.S. *Diabetes Care* 24:412, 2001
- <sup>3</sup>Colditz GA, Willett WC, Stampfer MJ, Manson JE, Hennekens CH, Arky RA, Speizer FE: Weight as a risk factor for clinical diabetes in women. *Am J Epidemiol* 132:501–513, 1990
- <sup>4</sup>Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH: The disease burden associated with overweight and obesity. *JAMA* 282:1523–1529, 1999
- <sup>5</sup>Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS, Marks JS: Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. *JAMA* 289:76–79, 2003
- <sup>6</sup>Field AE, Coakley EH, Must A, Spadano JL, Laird N, Dietz WH, Rimm E, Colditz GA: Impact of overweight on the risk of developing common chronic diseases during a 10-year period. *Arch Intern Med* 161:1581–1586, 2001
- <sup>7</sup>Hu FB, Manson JE, Stampfer MJ, Colditz G, Liu S, Solomon CG, Willett WC: Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. *N Engl J Med* 345:790–797, 2001
- <sup>8</sup>Carey VJ, Walters EE, Colditz GA, Solomon CG, Willett WC, Rosner BA, Speizer FE, Manson JE: Body fat distribution and risk of non-insulin-dependent diabetes mellitus in women: the Nurses' Health Study. *Am J Epidemiol* 145:614–619, 1997
- <sup>9</sup>Chan JM, Rimm EB, Colditz GA, Stampfer MJ, Willett WC: Obesity, fat distribution, and weight gain as risk factors for clinical diabetes in men. *Diabetes Care* 17:961–969, 1994
- <sup>10</sup>Maggio CA, Pi-Sunyer FX: The prevention and treatment of obesity: application to type 2 diabetes. *Diabetes Care* 20:1744–1766, 1997
- <sup>11</sup>Pi-Sunyer FX: Comorbidities of overweight and obesity: current evidence and research issues. *Med Sci Sports Exerc* 31:S602–S608, 1999
- <sup>12</sup>Pi-Sunyer FX: Medical hazards of obesity. *Ann Intern Med* 119:655–660, 1993
- <sup>13</sup>Wilson PW, D'Agostino RB, Sullivan L, Parise H, Kannel WB: Overweight and obesity as determinants of cardiovascular risk: the Framingham experience. *Arch Intern Med* 162:1867–1872, 2002
- <sup>14</sup>Krauss RM, Winston M, Fletcher RN, Grundy SM: Obesity: impact of cardiovascular disease. *Circulation* 98:1472–1476, 1998
- <sup>15</sup>Lew EA, Garfinkel L: Variations in mortality by weight among 750,000 men and women. *J Chronic Dis* 32:563–576, 1979
- <sup>16</sup>National Institutes of Health, National Heart, Lung and Blood Institute, National Institute of Diabetes and Digestive and Kidney Diseases: *Clinical Guidelines on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults*. Bethesda, Md., National Institutes of Health, 1998
- <sup>17</sup>Klein S, Wadden T, Sugerman HJ: AGA technical review on obesity. *Gastroenterology* 123:882–932, 2002
- <sup>18</sup>Leung WY, Neil TG, Chan JC, Tomlinson B: Weight management and current options in pharmacotherapy: orlistat and sibutramine. *Clin Ther* 25:58–80, 2003
- <sup>19</sup>Bray GA, Greenway FL: Current and potential drugs for treatment of obesity. *Endocr Rev* 20:805–875, 1999
- <sup>20</sup>Brolin RE: Bariatric surgery and long-term control of morbid obesity. *JAMA* 288:2793–2796, 2002
- <sup>21</sup>Franz MJ, Bantle JP, Beebe CA, Brunzell JD, Chiasson JL, Garg A, Holzmeister LA, Hoogwerf B, Mayer-Davis E, Mooradian AD, Purnell JQ, Wheeler M: Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications. *Diabetes Care* 26 (Suppl. 1):S51–S61, 2003
- <sup>22</sup>Olefsky J, Reaven GM, Farquhar JW: Effects of weight reduction on obesity: studies of lipid and carbohydrate metabolism in normal and hyperlipoproteinemic subjects. *J Clin Invest* 53:64–76, 1974
- <sup>23</sup>Henry RR, Scheaffer L, Olefsky JM: Glycemic effects of intensive caloric restriction and isocaloric refeeding in noninsulin-dependent diabetes mellitus. *J Clin Endocrinol Metab* 61:917–925, 1985
- <sup>24</sup>Pi-Sunyer FX: Short-term medical benefits and adverse effects of weight loss. *Ann Intern Med* 119:722–726, 1993
- <sup>25</sup>Goldstein DJ: Beneficial health effects of modest weight loss. *Int J Obes Relat Metab Disord* 16:397–415, 1992
- <sup>26</sup>Williams KV, Kelley DE: Metabolic consequences of weight loss on glucose metabolism and insulin action in type 2 diabetes. *Diabetes Obes Metab* 2:121–129, 2000
- <sup>27</sup>Torgerson JS, Hauptman J, Boldrin MN, Sjostrom L: XENical in the Prevention of Diabetes in Obese Subjects (XENDOS) study: a randomized study of orlistat as an adjunct to lifestyle changes for the prevention of type 2 diabetes in obese patients. *Diabetes Care* 27:155–161, 2004
- <sup>28</sup>UK Prospective Diabetes Study 7: response of fasting plasma glucose to diet therapy in newly presenting type II diabetic patients, UKPDS Group. *Metabolism* 39:905–912, 1990
- <sup>29</sup>Watts NB, Spanheimer RG, DiGirolamo M, Gebhart SS, Musey VC, Siddiqi YK, Phillips LS: Prediction of glucose response to weight loss in patients with non-insulin-dependent diabetes mellitus. *Arch Intern Med* 150:803–806, 1990
- <sup>30</sup>Dixon JB, O'Brien PE: Health outcomes of severely obese type 2 diabetic subjects 1 year after laparoscopic adjustable gastric banding. *Diabetes Care* 25:358–363, 2002
- <sup>31</sup>Kral J: Surgical interventions of obesity. In *Eating Disorders and Obesity: A Comprehensive Handbook*. Brownell KD, Fairburn C, Eds. New York, NY, Guilford, 1995, p. 510–515
- <sup>32</sup>Pories WJ, Swanson MS, MacDonald KG, Long SB, Morris PG, Brown BM, Barakat HA, deRamon RA, Israel G, Dolezal JM, et al.: Who would have thought it? An operation proves to be the most effective therapy for adult-onset diabetes mellitus. *Ann Surg* 222:339–350, 1995
- <sup>33</sup>Sugerman HJ, Starkey JV, Birkenhauer R: A randomized prospective trial of gastric bypass versus vertical banded gastroplasty for morbid obesity and their effects on sweets versus non-sweets eaters. *Ann Surg* 205:613–624, 1987
- <sup>34</sup>Reisin E, Abel R, Modan M, Silverberg DS, Eliahou HE, Modan B: Effect of weight loss without salt restriction on the reduction of blood pressure in overweight hypertensive patients. *N Engl J Med* 298:1–6, 1978
- <sup>35</sup>Trials of Hypertension Prevention Collaborative Research Group: Effects of weight loss and sodium reduction intervention on blood pressure and hypertension incidence in overweight people with high-normal blood pressure: the Trials of Hypertension Prevention, phase II. *Arch Intern Med* 157:657–667, 1997
- <sup>36</sup>He J, Whelton PK, Appel LJ, Charleston J, Klag MJ: Long-term effects of weight loss and dietary sodium reduction on incidence of hypertension. *Hypertension* 35:544–549, 2000
- <sup>37</sup>Mertens IL, Van Gaal LF: Overweight, obesity, and blood pressure: the effects of modest weight reduction. *Obes Res* 8:270–278, 2000
- <sup>38</sup>Stevens VJ, Obarzanek E, Cook NR, Lee IM, Appel LJ, Smith WD, Milas NC, Mattfeldt-Beman M, Belden L, Bragg C, Millstone M, Raczynski J, Brewer A, Singh B, Cohen J: Long-term weight loss and changes in blood pressure: results of the Trials of Hypertension Prevention, phase II. *Ann Intern Med* 134:1–11, 2001
- <sup>39</sup>Dattilo AM, Kris-Etherton PM: Effects of weight reduction on blood lipids and lipoproteins: a meta-analysis. *Am J Clin Nutr* 56:320–328, 1992
- <sup>40</sup>Van Gaal LF, Wauters MA, De Leeuw IH: The beneficial effects of modest weight loss on cardiovascular risk factors. *Int J Obes Relat Metab Disord* 21 (Suppl. 1):S5–S9, 1997
- <sup>41</sup>Ditschuneit HH, Flechtner-Mors M, Johnson TD, Adler G: Metabolic and weight-loss effects of a long-term dietary intervention in obese patients. *Am J Clin Nutr* 69:198–204, 1999
- <sup>42</sup>Metz JA, Stern JS, Kris-Etherton P, Reusser ME, Morris CD, Hatton DC, Oparil S, Haynes RB, Resnick LM, Pi-Sunyer FX, Clark S, Chester L, McMahon M, Snyder GW, McCarron DA: A randomized trial of improved weight loss with a prepared meal plan in overweight and obese patients: impact on cardiovascular risk reduction. *Arch Intern Med* 160:2150–2158, 2000
- <sup>43</sup>Tchernof A, Nolan A, Sites CK, Ades PA, Poehlman ET: Weight loss reduces C-reactive protein levels in obese postmenopausal women. *Circulation* 105:564–569, 2002
- <sup>44</sup>Ziccardi P, Nappo F, Giugliano G, Esposito K, Marfella R, Cioffi M, D'Andrea F, Molinari AM, Giugliano D: Reduction of inflammatory cytokine concentrations and improvement of endothelial functions in obese women after weight loss over one year. *Circulation* 105:804–809, 2002
- <sup>45</sup>Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, Nathan DM: Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 346:393–403, 2002

- <sup>46</sup>Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, Hu ZX, Lin J, Xiao JZ, Cao HB, Liu PA, Jiang XG, Jiang YY, Wang JP, Zheng H, Zhang H, Bennett PH, Howard BV: Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance: the Da Qing IGT and Diabetes Study. *Diabetes Care* 20:537-544, 1997
- <sup>47</sup>Tuomilehto J, Lindstrom J, Eriksson JG, Valle TT, Hamalainen H, Ilanne-Parikka P, Keinanen-Kiukaanniemi S, Laakso M, Louheranta A, Rastas M, Salminen V, Uusitupa M: Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med* 344:1343-1350, 2001
- <sup>48</sup>Vidal J: Updated review on the benefits of weight loss. *Int J Obes Relat Metab Disord* 26 (Suppl. 4):S25-S28, 2002
- <sup>49</sup>Anderson JW, Konz EC: Obesity and disease management: effects of weight loss on comorbid conditions. *Obes Res* 9 (Suppl. 4):326S-334S, 2001
- <sup>50</sup>Blackburn G: Effect of degree of weight loss on health benefits. *Obes Res* 3 (Suppl. 2):211S-216S, 1995
- <sup>51</sup>National Institutes of Health, National Heart, Lung and Blood Institute, North American Association for the Study of Obesity: *The Practical Guide: Identification, Evaluation, and Treatment of Overweight and Obesity in Adults*. Bethesda, MD, National Institutes of Health, 2000
- <sup>52</sup>Wing RR: Behavioral interventions for obesity: recognizing our progress and future challenges. *Obes Res* 11 (Suppl.):3S-6S, 2003
- <sup>53</sup>Wadden TA, Foster GD, Letizia KA: One-year behavioral treatment of obesity: comparison of moderate and severe caloric restriction and the effects of weight maintenance therapy. *J Consult Clin Psychol* 62:165-171, 1994
- <sup>54</sup>National Task Force on the Prevention and Treatment of Obesity, National Institutes of Health: Very low-calorie diets. *JAMA* 270:967-974, 1993
- <sup>55</sup>Weinsier RL, Wilson LJ, Lee J: Medically safe rate of weight loss for the treatment of obesity: a guideline based on risk of gallstone formation. *Am J Med* 98:115-117, 1995
- <sup>56</sup>Klem ML, Wing RR, McGuire MT, Seagle HM, Hill JO: A descriptive study of individuals successful at long-term maintenance of substantial weight loss. *Am J Clin Nutr* 66:239-246, 1997
- <sup>57</sup>Yu-Poth S, Zhao G, Etherton T, Naglak M, Jonnalagadda S, Kris-Etherton PM: Effects of the National Cholesterol Education Program's Step I and Step II dietary intervention programs on cardiovascular disease risk factors: a meta-analysis. *Am J Clin Nutr* 69:632-646, 1999
- <sup>58</sup>Saris WH, Astrup A, Prentice AM, Zunft HJ, Formiguera X, Verboeket-van de Venne WP, Raben A, Poppitt SD, Seppelt B, Johnston S, Vasilaras TH, Keogh GF: Randomized controlled trial of changes in dietary carbohydrate/fat ratio and simple vs complex carbohydrates on body weight and blood lipids: the CARMEN study. The Carbohydrate Ratio Management in European National diets. *Int J Obes Relat Metab Disord* 24:1310-1318, 2000
- <sup>59</sup>Lichtenstein AH, Van Horn L: Very low fat diets. *Circulation* 98:935-939, 1998
- <sup>60</sup>Grundy SM: Hypertriglyceridemia, insulin resistance, and the metabolic syndrome. *Am J Cardiol* 83:25F-29F, 1999
- <sup>61</sup>Garg A, Bonanome A, Grundy SM, Zhang ZJ, Unger RH: Comparison of a high-carbohydrate diet with a high-monounsaturated-fat diet in patients with non-insulin-dependent diabetes mellitus. *N Engl J Med* 319:829-834, 1988
- <sup>62</sup>Garg A, Grundy SM, Unger RH: Comparison of effects of high and low carbohydrate diets on plasma lipoproteins and insulin sensitivity in patients with mild NIDDM. *Diabetes* 41:1278-1285, 1992
- <sup>63</sup>Garg A, Bantle JP, Henry RR, Coulston AM, Griver KA, Raatz SK, Brinkley L, Chen YD, Grundy SM, Huet BA: Effects of varying carbohydrate content of diet in patients with non-insulin-dependent diabetes mellitus. *JAMA* 271:1421-1428, 1994
- <sup>64</sup>Foster GD, Wyatt HR, Hill JO, McGuckin BG, Brill C, Mohammed BS, Szapary PO, Rader DJ, Edman JS, Klein S: A randomized trial of a low-carbohydrate diet for obesity. *N Engl J Med* 348:2082-2090, 2003
- <sup>65</sup>Samaha FF, Iqbal N, Seshadri P, Chicano KL, Daily DA, McGrory J, Williams T, Williams M, Gracely EJ, Stern L: A low-carbohydrate as compared with a low-fat diet in severe obesity. *N Engl J Med* 348:2074-2081, 2003
- <sup>66</sup>Brehm BJ, Seeley RJ, Daniels SR, D'Alessio DA: A randomized trial comparing a very low carbohydrate diet and a calorie-restricted low fat diet on body weight and cardiovascular risk factors in healthy women. *J Clin Endocrinol Metab* 88:1617-1623, 2003
- <sup>67</sup>Stern L, Iqbal N, Seshadri P, Chicano KL, Daily DA, McGrory J, Williams M, Gracely EJ, Samaha FF: The effects of low-carbohydrate versus conventional weight loss diets in severely obese adults: one-year follow-up of a randomized trial. *Ann Intern Med* 140:778-785, 2004
- <sup>68</sup>Yancy WS Jr, Olsen MK, Guyton JR, Bakst RP, Westman EC: A low-carbohydrate, ketogenic diet versus a low-fat diet to treat obesity and hyperlipidemia: a randomized, controlled trial. *Ann Intern Med* 140:769-777, 2004
- <sup>69</sup>Ebbeling CB, Leidig MM, Sinclair KB, Hangen JP, Ludwig DS: A reduced-glycemic load diet in the treatment of adolescent obesity. *Arch Pediatr Adolesc Med* 157:773-779, 2003
- <sup>70</sup>Rolls BJ, Bell EA: Dietary approaches to the treatment of obesity (Review). *Med Clin North Am* 84:401-418, 2000
- <sup>71</sup>McGuire MT, Wing RR, Klem ML, Seagle HM, Hill JO: Long-term maintenance of weight loss: do people who lose weight through various weight loss methods use different behaviors to maintain their weight? *Int J Obes Relat Metab Disord* 22:572-577, 1998
- <sup>72</sup>Heber D, Ashley JM, Wang HJ, Elashoff RM: Clinical evaluation of a minimal intervention meal replacement regimen for weight reduction. *J Am Coll Nutr* 13:608-614, 1994
- <sup>73</sup>Jeffery RW, Wing RR, Thorson C, Burton LR, Raether C, Harvey J, Mullen M: Strengthening behavioral interventions for weight loss: a randomized trial of food provision and monetary incentives. *J Consult Clin Psychol* 61:1038-1045, 1993
- <sup>74</sup>Wing RR, Jeffery RW: Food provision as a strategy to promote weight loss. *Obes Res* 9 (Suppl. 4):271S-275S, 2001
- <sup>75</sup>Krauss RM, Eckel RH, Howard B, Appel LJ, Daniels SR, Deckelbaum RJ, Erdman JW Jr, Kris-Etherton P, Goldberg IJ, Kotchen TA, Lichtenstein AH, Mitch WE, Mullis R, Robinson K, Wylie-Rosett J, St Jeor S, Suttie J, Tribble DL, Bazzarre TL: AHA Dietary Guidelines: revision 2000: a statement for healthcare professionals from the Nutrition Committee of the American Heart Association. *Circulation* 102:2284-2299, 2000
- <sup>76</sup>Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults: Executive Summary of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *JAMA* 285:2486-2497, 2001
- <sup>77</sup>US Department of Health and Human Services: *The Surgeon General's Call to Action to Prevent and Decrease Overweight and Obesity, 2001*. Rockville, Md., U.S. Government Printing Office, 2001
- <sup>78</sup>Wing RR: Exercise and weight control. In *Handbook of Exercise in Diabetes*. Ruderman N, Devlin JT, Schneider SH, Eds. Alexandria, Va., American Diabetes Association, 2002, p. 355-364
- <sup>79</sup>Wing RR, Hill JO: Successful weight loss maintenance. *Annu Rev Nutr* 21:323-341, 2001
- <sup>80</sup>US Department of Health and Human Services: *Physical Activity and Health: A Report of the Surgeon General: Centers for Disease Control and Prevention and National Center for Chronic Disease Prevention and Health Promotion*, 1996. Washington, DC, U.S. Government Printing Office, 1996
- <sup>81</sup>Hu FB, Sigal RJ, Rich-Edwards JW, Colditz GA, Solomon CG, Willett WC, Speizer FE, Manson JE: Walking compared with vigorous physical activity and risk of type 2 diabetes in women: a prospective study. *JAMA* 282:1433-1439, 1999
- <sup>82</sup>Wei M, Gibbons LW, Mitchell TL, Kampert JB, Lee CD, Blair SN: The association between cardiorespiratory fitness and impaired fasting glucose and type 2 diabetes mellitus in men. *Ann Intern Med* 130:89-96, 1999
- <sup>83</sup>Church TS, Cheng YJ, Earnest CP, Barlow CE, Gibbons LW, Priest EL, Blair SN: Exercise capacity and body composition as predictors of mortality among men with diabetes. *Diabetes Care* 27:83-88, 2004
- <sup>84</sup>Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, Buchner D, Ettinger W, Heath GW, King AC: Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA* 273:402-407, 1995
- <sup>85</sup>Zinman B, Ruderman N, Campaigne BN, Devlin JT, Schneider SH: Physical activity/exercise and diabetes mellitus. *Diabetes Care* 26 (Suppl. 1):S73-S77, 2003
- <sup>86</sup>Thompson PD, Buchner D, Pina IL, Balady GJ, Williams MA, Marcus BH, Berra K, Blair

SN, Costa F, Franklin B, Fletcher GF, Gordon NF, Pate RR, Rodriguez BL, Yancey AK, Wenger NK: Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease: a statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity). *Circulation* 107:3109–3116, 2003

<sup>87</sup>NIH Consensus Development Panel on Physical Activity and Cardiovascular Health: Physical activity and cardiovascular health. *JAMA* 276:241–246, 1996

<sup>88</sup>Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, Froelicher VF, Leon AS, Pina IL, Rodney R, Simons-Morton DA, Williams MA, Bazzarre T: Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation* 104:1694–1740, 2001

<sup>89</sup>Schoeller DA, Shay K, Kushner RF: How much physical activity is needed to minimize weight gain in previously obese women? *Am J Clin Nutr* 66:551–556, 1997

<sup>90</sup>Estabrooks PA, Glasgow RE, Dziewaltowski DA: Physical activity promotion through primary care. *JAMA* 289:2913–2916, 2003

<sup>91</sup>American College of Sports Medicine: The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med Sci Sports Exerc* 30:975–991, 1998

<sup>92</sup>Gibbons RJ, Balady GJ, Beasley JW, Bricker JT, Duvernoy WF, Froelicher VF, Mark DB, Marwick TH, McCallister BD, Thompson PD Jr,

Winters WL, Yanowitz FG, Ritchie JL, Gibbons RJ, Chaitman MD, Eagle KA, Gardner TJ, Garson A Jr, Lewis RP, O'Rourke RA, Ryan TJ: ACC/AHA guidelines for exercise testing: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). *J Am Coll Cardiol* 30:260–311, 1997

<sup>93</sup>Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, Mark DB, McCallister BD, Mooss AN, O'Reilly MG, Winters WL Jr, Gibbons RJ, Antman EM, Alpert JS, Faxon DP, Fuster V, Gregoratos G, Hiratzka LF, Jacobs AK, Russell RO, Smith SC Jr: ACC/AHA 2002 guideline update for exercise testing: summary article: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines). *Circulation* 106:1883–1892, 2002

<sup>94</sup>American Diabetes Association: Standards of medical care in diabetes (Position Statement). *Diabetes Care* 27 (Suppl. 1):S15–S35, 2004

<sup>95</sup>Dunn AL, Marcus BH, Kampert JB, Garcia ME, Kohl HW III, Blair SN: Comparison of lifestyle and structured interventions to increase physical activity and cardiorespiratory fitness: a randomized trial. *JAMA* 281:327–334, 1999

<sup>96</sup>Mayer-Davis EJ, D'Agostino R Jr, Karter AJ, Haffner SM, Rewers MJ, Saad M, Bergman RN: Intensity and amount of physical activity in relation to insulin sensitivity: the Insulin Resistance Atherosclerosis Study. *JAMA* 279:669–674, 1998

<sup>97</sup>Andersen RE, Wadden TA, Bartlett SJ, Zemel B, Verde TJ, Franckowiak SC: Effects of

lifestyle activity vs structured aerobic exercise in obese women: a randomized trial. *JAMA* 281:335–340, 1999

<sup>98</sup>Perri MG, Martin AD, Leermakers EA, Sears SF, Notelovitz M: Effects of group- versus home-based exercise in the treatment of obesity. *J Consult Clin Psychol* 65:278–285, 1997

<sup>99</sup>Jakicic JM, Wing RR, Butler BA, Robertson RJ: Prescribing exercise in multiple short bouts versus one continuous bout: effects on adherence, cardiorespiratory fitness, and weight loss in overweight women. *Int J Obes* 19:893–901, 1995

<sup>100</sup>Jakicic JM, Winters C, Lang W, Wing RR: Effects of intermittent exercise and use of home exercise equipment on adherence, weight loss, and fitness in overweight women: a randomized trial. *JAMA* 282:1554–1560, 1999

<sup>101</sup>Anderson DA, Wadden TA: Treating the obese patient: suggestions for primary care practice. *Arch Fam Med* 8:156–167, 1999

<sup>102</sup>Poston WS, Foreyt JP: Successful management of the obese patient. *Am Fam Physician* 61:3615–3622, 2000

<sup>103</sup>Wing RR, Gorin A, Tate D: Strategies for changing eating and exercise behavior. In *Present Knowledge in Nutrition*. 8th ed. Bowman BA, Russell RM, Eds. Washington, D.C., ILSI, 2001, p. 650–661

<sup>104</sup>Wadden TA, Foster GD: Behavioral treatment of obesity. *Med Clin North Am* 84:441–461, vii, 2000

<sup>105</sup>American Diabetes Association: Screening for type 2 diabetes (Position Statement). *Diabetes Care* 27 (Suppl. 1):S11–S14, 2004